QUANTITATIVE DISTRIBUTION OF ARSENIC IN VARIOUS PARTS OF THE BODY AFTER BEING FED TO THE AMERICAN ROACH, *PERIPLANETA AMERICANA* (LINN.)

BY

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ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENTOMOLOGY IN THE GRADUATE SCHOOL OF THE UNIVERSITY OF ILLINOIS, 1940

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INTRODUCTION

In most of the recorded studies on the toxicity of arsenical compounds to invertebrate animals only post-lethal determinations have been made. The quantitative dispersion of arsenic through the body of the animal and the relative speed of this dispersion have been neglected. Knowledge of the movement of arsenical compounds within the animal will aid in the evaluation of their toxic properties.

The purpose of this paper, therefore, is to present an accurate study of the movements of sodium metarsenite through the alimentary canal of the American roach, *Periplaneta americana* (Linn.).

HISTORY OF ARSENIC

The poisonous properties of arsenic were recognized in the middle ages and this substance was used by professional poisoners of those times. In modern medicine forms of inorganic arsenical salts are used for the treatment of dyspepsia and anaemia, and aromatic organic forms are used for the treatment of amoebic dysentery, sleeping sickness and syphilis.

The toxicity of arsenic is thought to be produced by its chemical combination with certain cellular constituents, probably glutathione. This substance is active in the oxidation processes of protoplasm and its inactivation in combination with arsenic produces asphyxiation of the cell. Arsenic also manifests a paralytic action on the central nervous system.

Arsenical compounds such as white arsenic and sodium arsenite are able to penetrate the body wall of insects and produce death. The physiological effects of arsenic upon insects have been studied. Arsenic will produce a cessation of the action of the heart and a reduction of the respiration rate. It has been shown that arsenic combines with glutathione or similar compounds in the cell to nullify nitroprusside results.

CHEMICAL METHOD

After a thorough study of quantitative methods for the determination of arsenic a modification involving the electrolytic production of hydrogen in arsenical solutions with the resultant formation of arsine gas was utilized. The arsine gas was reacted with mercuric bromide paper strips and this reaction formed colored precipitates on the paper strips. The amount of arsenic in the solution could be determined by the extent of the colored area on the paper strip when compared with like strips from known amounts of arsenic.

TECHNICAL PROCEDURE

Determination of the movements of sodium metarsenite through the digestive tract of the American roach, *Periplaneta americana* (Linn.), and the absorption of this salt from the digestive tract necessitated an accurate technical procedure. This procedure was divisible into three main stages: (1) feeding of known amounts of arsenic, (2) the dissection of the roach at definite periods after feeding, and the subsequent preparation of the tissues for quantitative arsenic determination, and (3) the quantitative determination of arsenic by chemical methods.

(1) *The Feeding of Known Amounts of Arsenic*

The roaches used for all determinations were adults of the American roach. These insects were selected because of their size and ease of handling. The animals, well fed and watered, were kept in a wire cage allowing room for exercise and abundant air supply. Except for choosing equal numbers of males and females, the animals for determinations were chosen at random from groups of apparently healthy individuals. Before being used, each roach was confined for twenty-four hours in a glass container and supplied only with water. The purpose of this fast was to eliminate, as far as possible, the presence of food material in the digestive tract.

It was necessary to design a cell in which the roach could be confined in a suitable position during the feeding process.

This feeding cell was constructed of sheet tin and consisted of three parts: a rectangular tray for holding the roach, a sliding cover for confining the legs and abdomen of the roach, and a sliding panel which fitted firmly into slots in the side of the tray and when in position was inserted between the head and thorax of the insect. A notch was fashioned in the middle of the lower side of the panel so that when the panel was in place it encompassed the ventral and lateral surfaces of the roach's cervix and without exerting much pressure held the head of the animal stationary. In preparation for feeding, the roach was placed on its back in the tray. The sliding panel was fitted into place and prevented the roach from escaping. The sliding cover was used to prevent vigorous leg movements prompted by the roach's endeavors to escape. The roach ceased to struggle after this cover was in place and remained quiescent, for the most part, during the feeding of the arsenic solution.

In order to determine the amount of arsenic fed to the roaches, a known solution of sodium metarsenite had to be accurately prepared. Twenty grams of Baker's chemically pure sodium metarsenite ($NaAsO_2$) were carefully weighed on a chainomatic balance sensitive to 0.05 milligrams. The sodium metarsenite was then dissolved in one thousand grams of distilled water. Since the total solution weighed one thousand and twenty grams and of this twenty grams was sodium metarsenite each gram of solution contained one-sixtieth or 0.01667 grams of the sodium metarsenite. Multiplying by the gravimetric factor for arsenic in sodium metarsenite or 0.5768, it was shown that each gram of solution contained 0.0096153 grams or 9.6153 milligrams of arsenic.

The roaches were fed the sodium metarsenite solution by means of a 1 cc. Luer syringe fitted with a one inch short-tipped needle. The syringe was held firmly in a wooden side-arm attached to a ratchet and pinion so that it could be raised and lowered during the feeding process. The feeding cell was mounted on a block of wood and arranged so that the syringe needle, on being lowered, entered the mouth cavity of the roach. A drop of the sodium metarsenite solution was carefully forced out on the end of the syringe needle and care-

fully lowered. The drop on coming in contact with the mouth parts of the roach was quickly swallowed. The process was then repeated until a required amount of the sodium metarsenite had been administered. The amount of sodium metarsenite fed was determined by the difference in weight of the syringe before and after feeding.

As each drop of the arsenical solution was fed it was observed through a mounted hand lens to insure that it was taken in entirety by the roach. If the roach did not swallow the total dose or regurgitated during the feeding process it was discarded from further determination.

It was not possible to determine accurately the body weight of the roach either before or after the animal had been mounted in the feeding cell. The loss of water vapor from the struggles of the animal during handling, and the occurrence of defecation after the feeding had begun, in the majority of cases, produced significant and variable decreases in the body weight. For these reasons after the arsenical solution had been fed the roach was removed from the feeding cell, placed in a glass container, and weighed.

Since the initial body weight of the roach, just previous to feeding, could not be accurately determined, it was impossible to calculate the number of milligrams of solution to be administered in order to give a standard dosage of arsenic in terms of milligrams per gram of body weight of the insect. Therefore an approximated standard dosage of ten milligrams of arsenical solution containing 0.0961 milligrams of arsenic was fed to each roach. Some variation of the dosage was introduced by inability to control the size of the drops administered, but since the dosage was weighed with an accuracy of 0.05 milligrams the amount of arsenic fed to each roach was known with an accuracy of $\pm$ 0.0009 milligrams.

After the body weight of the roach had been determined, the animal was confined in a glass Petri dish and kept supplied with water only.

(2) *Dissection and Preparation of the Tissues for Determination*

At a definite interval of time after feeding, the roach was removed from the Petri dish and mounted on its back in a

dissection dish. The animal was held in position by pins inserted in the pronotum and the distal portions of the wings.

A blood sample was obtained by inserting a glass tube drawn to capillary size of 0.5 mm. diameter at one end. The tube was inserted through the membrane at the coxal-trochantal articulation of one hind leg so that it entered the interior of the coxa. The blood, under capillary action, collected in the tube. An effort was made to obtain a definite amount of blood from each roach by filling the tube to a mark scratched on its surface. It was often necessary to augment the blood sample from the hind leg by severing other legs at the coxa and collecting the droplets of blood which formed at the severed ends. The blood was then expelled from the tube into a small round-bottomed 10 cc. glass container. The subsequent treatment of the sample will be considered later.

The coxa of the other hind leg was used as a muscle sample and after removal from the body was placed in a round-bottomed container.

The dissection of the digestive tract was performed in the following manner. Longitudinal incisions were made along the lateral margins of the abdomen from the cerci to the second abdominal segment. These incisions were connected by a transverse incision through the ventral body wall of the second abdominal segment. It was then possible carefully to fold back the entire ventral wall of the abdomen partially exposing the digestive tract. The posterior end of the rectum was ligated by means of silk thread and the digestive tube was cut through behind the ligature. By grasping the digestive tract at the ligature and exerting a gentle, steady pull, the coiled mid and hind intestines were drawn out into a straight tube. Ligatures of silk thread were placed at the posterior end of the crop, proventriculus, ventriculus and large intestine. At this point the neck of the insect was grasped with tweezers and by firmly but slowly pulling the head away from the thorax the entire alimentary canal was drawn through the break between the neck and the prothorax and freed from the body. Still held by the tweezers the digestive

tract was divided into sections by successive cuts just posterior to each ligature. In this manner the rectum, the intestine and Malpighian tubules, the ventriculus and gastric caecae, the proventriculus, and the crop were separated and placed in individual round-bottomed glass containers. The crop was separated from the head by a cut made as far anterior as possible.

The head and salivary glands, the thorax exclusive of the legs and wings, and the abdomen including the fat bodies and reproductive organs were each treated as a composite sample and placed in round-bottomed containers.

The round-bottomed 10 cc. glass containers used to hold the samples had been previously weighed. The weights of the samples were now recorded. One cc. of a 50% dilution of concentrated sulphuric acid was added to each sample. The samples were ground with a pestle until all tissue particles had been reduced to a fine state. Three cc. of water were slowly added with stirring to each sample. The resultant solution was an approximate 12.5% dilution of concentrated sulphuric acid. The weight of each sample solution was then determined. Known amounts of these samples were then used in the final determination of the arsenic content of the respective tissues.

Since the roaches were killed at definite intervals after feeding it was possible to trace the passage of arsenic through the alimentary canal and its distribution in the body. The time intervals after feeding were selected arbitrarily as one-half hour intervals.

(3) *The Quantitative Determination of the Arsenic*

The quantitative determinations of arsenic were carried out in a determination unit similar to that of Fink (1927) with the substitution of lead for platinum foil as the anode. The determination unit was a U-shaped, hard glass tube with an inside diameter of one centimeter. The unit was eleven centimeters in height and had a volumetric capacity of fifteen cubic centimeters. A ground glass stopper fitted firmly into each arm of the unit. Electrodes of pure sheet lead 1″ x 2.5″ were suspended from platinum wires fused through

the ground glass stoppers. Each arm of the U-tube was equipped with a sidearm having an inside diameter of five millimeters. These sidearms intersected the main arms of the U-tube about one centimeter from the end. The anode sidearm was a straight tube four centimeters in length, while the cathode sidearm was eight centimeters in length and was bent upward at a right angle in the middle. Attached to this cathode sidearm by means of rubber tubing was an additional glass tube thirty centimeters long bent so that strips of mercuric bromide paper could be inserted in a horizontal position.

The strips of mercuric bromide paper were prepared from special quality filter paper of uniform thickness sold by Reeve Angel in strips four millimeters wide and twelve centimeters in length. These strips specially designed for arsenic determinations were cut in two and soaked for twenty-four hours in a carefully prepared 1.5% solution of mercuric bromide in absolute alcohol. Before being used these strips were removed from the alcohol solution and the excess mercuric bromide solution was forced off the paper. The strips, slightly dampened with alcohol, were placed in the cathode sidearm extension at the beginning of each determination. The mercuric bromide solution gradually deteriorated and it was necessary to prepare new strips every ten days.

A 12.5% dilution of concentrated sulphuric acid was found to be the best electrolyte. Ten cubic centimeters of this sulphuric acid, one cc. of amyl alcohol and a known aliquot portion of the sample solution were placed in the determination unit. Lead electrodes were set in place and a current of one ampere was passed through the solution for one hour.

The hydrogen generated by the electrolysis combined with any arsenic in the solution and the arsine evolved at the cathode passed through the cathode sidearm. A dry plug of cotton saturated with lead acetate was placed loosely in this cathode sidearm. Any impurities of hydrogen sulphide present in the arsine were removed by the lead acetate. The arsine gas then passed through the cathode sidearm extension and in doing so reacted with the mercuric bromide paper. This reaction produced an orange-brown coloration. By com-

parison of the coloration with that produced on mercuric bromide paper by a known amount of arsenic, the amount of arsenic in the aliquot portion of the sample solution was measured. The amount of arsenic present in the entire sample solution was determined by multiplying the results by an appropriate factor.

Roaches were fed water instead of sodium metarsenite solution and after similar preparational procedure sample solutions were run as blank determinations to ascertain the introduction of arsenic impurities at some stage of the procedure. The results from these blank runs were negative.

APPLICATION OF THE TECHNICAL PROCEDURE

Ten male and ten female roaches were used to determine the arsenic distribution at the end of each one-half hour period after feeding. It was necessary to continue the determination to six and one-half hours after feeding at which time the majority of the animals had succumbed and further experiments were not feasible. If an animal died in the interim between two one-half hour periods the determination values were placed in the longer period. The amounts of arsenic in milligrams in the individual samples were averaged to obtain a mean value for each of the sexes.

The dissection time required for the removal of the samples was approximately twenty minutes. The interval was divided so that the dissection of the abdomen began at multiples of one-half hour after the median feeding time. The average feeding time was 15 ± 5 minutes.

In order to evaluate the colored areas of the mercuric bromide strips from the action of the arsenic in the tissue samples it was necessary to prepare a series of colored strips from known amounts of arsenic. Ten portions of the standard sodium metarsenite solution for each 0.0001 gram interval from 0.0001 to 0.0010 grams of solution were used in successive preparations of the paper strips. Although there was some variation in the length of the colored area the mean values at each interval indicate that 0.00048 milligrams of arsenic or the amount contained in 0.0005 grams of solution

could be distinguished with accuracy. The variation in the lengths of the colored portions of the paper strips prevented any greater accuracy in distinguishing between the amounts of arsenic, but the presence of smaller amounts of arsenic than 0.00048 milligrams were indicated by slight coloration of the paper, and these traces are indicated at 0.0001 milligrams of arsenic.

SUMMARY OF RESULTS

The results of the determinations made on 260 adult roaches, *Periplaneta americana* (Linn.), were presented in table form. After administration of a standard dose of .0963 ± .0012 grams of arsenic as a sodium metarsenite solution the mean values of arsenic in a series of samples were recorded.

The mean value of the crop sample showed a gradual decrease in arsenic content in the adult males from .0947 ± .0019 milligrams of arsenic at one-half hour after feeding to .0410 ± .0052 milligrams of arsenic at six and one-half hours after feeding; in the females from 0.0936 ± .0013 milligrams of arsenic to .0415 ± .0055 milligrams of arsenic.

Arsenic was not detected in the proventriculus until 1 ± 0.5 hours after feeding in either sex. The mean value of the proventriculus sample showed an increase in arsenic content in the males from .0006 ± .0004 milligrams of arsenic at one hour after feeding to .0052 ± .0007 milligrams of arsenic at six and one-half hours after feeding; in the females from .0003 ± .0004 milligrams of arsenic to .0051 ± .0008 milligrams of arsenic in the same length of time. The arsenic content of the proventriculus appeared to approach an average value of .0050 milligrams of arsenic at time intervals of four hours or more after feeding.

Arsenic appeared in the ventriculus sample in 1.5 ± 0.5 hours after feeding. In the male roaches the mean arsenic value of the ventriculus sample showed an increase from .0004 ± .0004 milligrams of arsenic at one and one-half hours to .0277 ± .0023 milligrams of arsenic at six and one-half hours after feeding; in the female roaches the mean value

rose from .0002 ± .0003 milligrams of arsenic to .0276 ± .0018 milligrams of arsenic in the same length of time.

Arsenic appeared in the intestinal sample 3.0 ± 0.5 hours after feeding. In the male roaches the mean arsenic value of the sample showed an increase from .0004 ± .0006 milligrams of arsenic at two and one-half hours after feeding to .0080 ± .0009 milligrams of arsenic at six and one-half hours; in the female roaches from .0001 ± .0002 milligrams of arsenic to .0078 ± .0009 milligrams of arsenic in the same length of time.

Arsenic appeared in the rectum sample in 6.0 ± 0.5 hours after feeding. In both sexes the mean value of the arsenic in the sample approached .0002 ± .0002 milligrams of arsenic six and one-half hours after feeding.

Arsenic appeared in the blood and coxa samples in 4.5 ± 2.0 hours. The mean arsenic value of the blood sample did not exceed .0001 ± .0002 milligrams of arsenic at any interval after feeding. The mean arsenic value of the coxa sample did not exceed .0003 ± .0003 milligrams of arsenic at any interval after feeding.

Arsenic appeared in the head sample at all intervals after feeding and probably was present as residues on the mouthparts and in the mouth cavity from the administration of the dose. The mean of the mean values for the intervals of time up to four hours after feeding in the male roaches was .0021 ± .0005 milligrams of arsenic; for the female roaches it was .0022 ± .0004 milligrams of arsenic. In the time intervals greater than four hours the mean arsenic value of the head sample showed a gradual increase in the male roaches from .0024 ± .0016 milligrams of arsenic at four hours after feeding to .0046 ± .0012 milligrams of arsenic at six and one-half hours after feeding, while in the female roaches the mean arsenic value rose from .0025 ± .0013 milligrams of arsenic at four and one-half hours after feeding to .0045 ± .0010 milligrams of arsenic at six and one-half hours after feeding.

Arsenic appeared in the thorax sample in 3.5 ± 1.0 hours. The mean arsenic value in the male roaches rose from .0001 ± .0002 milligrams of arsenic at three hours after feeding to

.0032 ± .0007 milligrams of arsenic at six and one-half hours after feeding; in the female roaches the mean arsenic value rose from .0002 ± .0003 milligrams of arsenic at three and one-half hours after feeding to .0032 ± .0007 milligrams of arsenic at six and one-half hours after feeding.

Arsenic appeared in the abdomen sample in 3.5 ± 1.0 hours. The mean arsenic value in the male roaches rose from .0001 ± .0002 milligrams of arsenic at three hours after feeding to .0046 ± .0009 milligrams of arsenic at six and one-half hours after feeding; in the female roaches the mean arsenic value rose from .0002 ± .0004 milligrams of arsenic at three hours after feeding to .0046 ± .0009 milligrams of arsenic at six and one-half hours after feeding.

Some arsenic was not accounted for in the determinations and is recorded as the error. The mean value of error ranged from —.0004 to —.0048 milligrams of arsenic. The error may arise from several sources (1) the loss of small amounts of arsenic during the feeding process, (2) the loss of a certain portion of the haemolymph and other tissues during the dissection of the roach, and (3) the handling of the sample in preparation for the arsenic determination.

DISCUSSION

The absence of arsenic from the proventriculus at the end of one-half hour is surprising in the light of Snipes' work (1938). In his work a banana paste containing white arsenic was not delayed in entering the proventriculus but passed more slowly through the ventriculus than a pure banana paste. The semi-solid nature of the banana paste in his experiments may have modified the action of the arsenic. The slowness of the arsenic to penetrate the proventriculus suggests that a certain resistance to the passage of the arsenic may exist at this point.

The experiments demonstrate that the wall of the crop is not readily permeable to arsenic since any arsenic penetrating the crop wall would be revealed in the thorax sample. The appearance of arsenic in the thorax sample did not occur until shortly before the death of the animal. This observa-

tion substantiated the work of Abbott (1926) who stated that the crop wall was impermeable to water and water-soluble substances. While O'Kane and Glover (1935 and 1936) demonstrated that white arsenic could penetrate the body wall of insects, the penetration of toxic amounts required thirty-six hours. It is possible that after a longer period of time the arsenic might be able to penetrate the crop wall of the insect. The rapid death of the insect under the standard dosage administered prevented determination of this point.

The absorption of the arsenic from the alimentary canal occurs apparently in the ventriculus. In this case the absorption is relatively slow as arsenic appeared in the ventriculus sample at one and one-half hours after feeding but was not detected in the blood or abdomen samples until three hours after feeding. The possibility exists, however, that a very rapid absorption may take place in the intestine of the animal but since a chitinous lining similar to the fore-intestine exists in this region this supposition is not probable.

It is evident that once the arsenic has penetrated the wall of the alimentary tract it is dispersed throughout the body by the blood. The concentration of the arsenic in the abdomen sample suggests that it is held by organs in this region and is removed from the blood proper.

When death occurred the mean arsenic value of the abdominal sample in the females was .0049 ± .0006 milligrams of arsenic, the mean value of the thorax sample was .0032 ± .0006 milligrams of arsenic, and if .0021 milligrams of arsenic was taken as a mean value for the arsenic residues in the mouth then an increase of .0024 ± .0009 milligrams of arsenic occurred in the head sample at death. In the males at death the mean arsenic value of the abdominal sample was .0045 ± .0006 milligrams of arsenic, the mean value of the thorax sample was .0032 ± .0006 milligrams of arsenic, and if .0022 milligrams of arsenic was taken as a mean value for the arsenic residues in the mouth then an increase of .0026 ± .0009 milligrams of arsenic occurred in the head sample.

The mean weight of the female roaches which died was 0.9502 ± .0006 grams and the total amount of arsenic present

in the abdominal, thoracic and head samples was .0099 ± .0020 milligrams of arsenic. From the above results a lethal dose of .0105 milligrams of arsenic per gram of body weight was determined for the female animals. The mean weight of the male roaches which died was .8532 ± .0005 grams, and the total amount of arsenic present in the abdominal, thoracic and head samples was .0102 ± .0018 milligrams of arsenic. From the above results a lethal dose of .0119 milligrams of arsenic per gram of body weight was determined for the male animals.

This study is one of basic research and its practical application is not immediate. A comparison between this study and studies on other arsenical salts, or between different concentrations of sodium metarsenite should reveal data concerning the factors which influence arsenic absorption and toxicity. From these results more efficient arsenical insecticides may be evolved and applied. It is for these reasons that the problem was pursued.

CONCLUSIONS

1. The quantitative dispersion of sodium metarsenite in the body of the American cockroach, *Periplaneta americana* (Linn.), has been studied by measuring the amount of arsenic present in samples from various parts of the bodies of 260 individuals at definite periods after feeding.

2. After feeding a standard dosage of sodium metarsenite solution, arsenic appeared in the proventriculus of adult roaches of both sexes after 1.0 ± 0.5 hours, in the ventriculus after 1.5 ± 0.5 hours, in the intestine after 3.0 ± 0.5 hours, and in the rectum after 6.0 ± 0.5 hours.

3. Arsenic was absorbed in the ventriculus of the roaches and appeared in the blood after 4.5 ± 2.0 hours. The crop wall was apparently impermeable to arsenic.

4. At the time of death of female roaches averaging 0.9502 ± 0.0006 grams, approximately 0.0049 ± 0.0006 milligrams of arsenic were absorbed in the abdomen, 0.0032 ± 0.0006 milligrams in the thorax and 0.0024 ± 0.0009 milligrams in the head. At the time of the death of male roaches, averaging 0.8532 ± 0.0005 grams, approximately 0.0045 ± .0.0006

milligrams of arsenic were absorbed in the abdomen, 0.0032 ± 0.0006 milligrams of arsenic in the thorax, and 0.0026 ± 0.0009 milligrams of arsenic in the head.

5. The absorption of 0.0105 milligrams of arsenic per gram of body weight produced death in female roaches, while the absorption of 0.0119 milligrams of arsenic per gram of body weight produced death in the male roaches.

BIBLIOGRAPHY*

Abbott, R. L.

1926 Contributions to the Physiology of Digestion in the Australian roach, *periplaneta australasiae* Fab..
J. exp. Zool., 44:219-253 (1926).

Fink, D. E.

1927 A Modified Electro-Gutzeit Apparatus for the Quantitative Estimation of Minute Amounts of Arsenic in Insect Tissue.
J. biol. Chem., **72**, pt. 2:737-743 (1927).

O'Kane, W. C., and Glover, L. C.

1935 Penetration of Arsenic into Insects. Studied of Contact Insecticides. X.
N. Hamp. Sta. Tech. Bull. **63**:1-8 (1925).

————and————

1936 Further Determinations of the Penetration of Arsenic into Insects. Studies of Contact Insecticides. XI.
N. Hamp. Sta. Tech. Bull. **63**:1-8 (1935).

Snipes, B. T.

1938 Passage-time of Various Types of Normal and Poisoned Foods through the Alimentary Tract of the Cockroach, *Periplaneta americana* Linn..
Iowa Sta. Coll. J. Sci., **13**:93-94 (1938).

*This is an abbreviated bibliography containing only references from this abstract.

VITA

RICHARD WILLIAM FAY was born in Huron, South Dakota, October 1, 1912. He received his primary education in the Illinois School System at Elgin and Chicago, Illinois. His secondary education was received in the Chicago High School System, and he graduated with honors from the Nicholas Senn High School in June, 1930.

He entered Iowa State College, Ames, Iowa, the following September, enrolling in the Department of Zoology and Entomology from which he received the degree of Bachelor of Science in June, 1934, and a Master of Science degree in the same institution in June, 1935. His Master's thesis was "A Method for the Determination of Specific Gravity of Insect Blood and its Application to the American Cockroach, *Periplaneta americana* (Linn.)." This thesis was completed during the school year of 1935 when he was employed as a Research Fellow under a subsidy by the Rockefeller Research Institute, working under the direction of Dr. J. Franklin Yeager. During the summers of 1934 and 1935, he was employed by the Iowa State Agricultural Experiment Station as a field entomologist.

The author entered the University of Illinois, Urbana, Illinois, in September, 1935, to continue graduate work toward a doctorate degree. He was employed during the school years of 1936, 1937 and 1938, as a half-time graduate assistant in the Entomology Department, in which position he aided in the laboratory instruction in the beginning entomology course. During the summer of 1936, he was employed by the Illinois Natural History Survey where his duties were confined to light trap and codling moth studies. During the summer of 1937, he was employed as full-time instructor in entomology and assisted Dr. W. P. Hayes in the summer courses on insect morphology and field crop insects. During the summer of 1938 he was again employed by the Illinois Natural History Survey and conducted studies on the control of the common house fly. In the winter of 1938, in the employ of the Illinois Natural History Survey, he co-operated in the study of dry dips for the control of lice on domestic animals. In June, 1939, he entered the employ of W. B. McCloud & Company in

Chicago, Illinois, as entomologist and continued in this capacity until May, 1940. From this time on, he devoted full time to the completion of the foregoing problem.

He is a member of Phi Kappa Phi Honorary Society, the Entomological Society of America, and the American Association of Economic Entomologists.